CENTESIL: AN INDEPENDENT RESEARCH CENTRE ON POLYSILICON

C. del Cañizo* [1,3], A. Rodríguez[2,3], G. del Coso[1], L. Méndez[3], JC. Zamorano[1], G. Ovejero[2,3] and A. Luque[1,3]
[1] Instituto de Energía Solar, Universidad Politécnica de Madrid, Ciudad Universitaria, 28040 Madrid, Spain
[2] Dpto. Ingeniería Química, Universidad Complutense de Madrid, Ciudad Universitaria, 28040 Madrid, Spain
[3] Centro de Tecnología del Silicio Solar (CENTESIL), Eric Kandel 1, 28904 Getafe, Spain
* Corresponding author: canizo@ies-def.upm.es. Tel: 914533550 - Fax: 915446341

ABSTRACT: The tremendous expansion of the photovoltaic technology and its relative avidity for silicon is producing a dramatic change in the polysilicon industry structure, increasing the efforts to produce a low cost, high quality Solar Silicon. In this context, the Centro de Tecnología del Silicio Solar (CENTESIL) was founded in 2006 as a private-public partnership venture, and is currently building a 50 t/a pilot plant for silicon purification following the chlorosilane route. Although an advanced state of the art technology has been selected as first choice, the purpose is to be able to undertake developments in any topic that has the potential to reduce the cost effectively. Additionally, the project includes facilities for monocrystalline growth and wafering, and also the solar cell processing line of the Instituto de Energía Solar, so that it will cover the whole value chain from feedstock to solar cell.
Keywords: Silicon, chlorosilanes, CVD Based deposition

1 INTRODUCTION

The rapid growth of the PV sector in the last years has changed the focus of the polysilicon market, which in the past was mainly devoted to microelectronics, while now the demand of the PV sector is larger, and increasing. As the traditional suppliers were not prepared to attend this quickly growing demands, a silicon shortage scenario was experienced, with a dramatic growth in polysilicon prices and troubles for many companies to secure their polysilicon feedstock. Traditional polysilicon suppliers reacted expanding production, and a number of newcomers tried to enter the market, acquiring the technology by themselves or even exploring the viability of new sources of ultrapurified silicon.

The scenario has abruptly changed due to the economic crisis, the financial restrictions and the modified regulations of some PV regional markets such as Spain, so that the PV companies have experienced a slow down and reduced their requests of polysilicon, and many plans of installing new polysilicon capacity have been cancelled or postponed, making polysilicon prices quickly go down.

But this situation of overcapacity is temporary, because PV annual productions in the range of tens of GW are foreseen in some years, and new polysilicon capacity will have to be implemented. Then, issues such as material quality, energy consumption in the fabrication process and cost structure of the product come back to the foreground, making R&D contributions relevant when aiming at “Solar Silicon”.

2 AN INITIATIVE FOR R&D ON POLYSILICON

The analysis presented lead in 2006 to the foundation of the Centro de Tecnología del Silicio Solar, CENTESIL, as a private-public partnership venture owned by Universidad Politécnica de Madrid (29.5% of the shares), Universidad Complutense de Madrid (19.5%), and three companies (Isofotón, DCWafers and Técnicas Reunidas, each with 17%). By now it is a Spanish initiative, but it has the clear vocation of opening to an international partnership.

CENTESIL is currently building a 50 t/a pilot plant for silicon purification following a modernized chlorosilane route. The development contains four areas of activity: (1) synthesis of chlorosilanes, with the silicon tetrachloride, a process by-product, as the main source of chlorine; (2) chlorosilane purification based on fractional distillation but with additional processes when necessary to remove lifetime-killing impurities; (3) development of routes to reduce the energy consumption of the chemical vapor deposition and (4) recycling of the by-products for optimal use and sustainability.

To benefit from an integrated approach, the project includes facilities for ingot growth and wafering, and also the solar cell processing line of the Instituto de Energía Solar.

The plant is placed in a technological park in Getafe, a village south of Madrid, where a building of 2500 m^2 has been constructed (see Figure 1), of which 2000 m^2 are devoted to technological infrastructures.

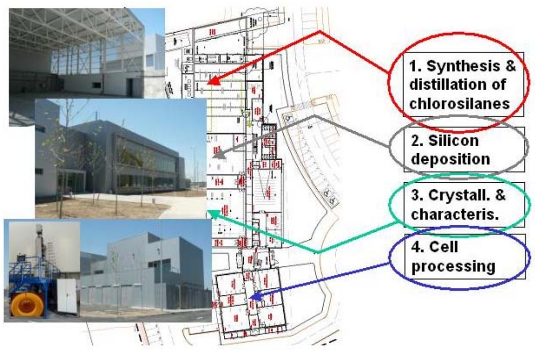

Figure 1: Sketch of the Centesil plant in TecnoGetafe Park with some views of the building.

3 CENTESIL PILOT PLANT

3.1 Steps taken to define the pilot plant

Some of the steps taken to define the pilot plant are briefly described now. They cover modelling, experimental developments at the laboratory scale and design and engineering of the pilot plant.

At CENTESIL we performed an analysis of

alternatives for chlorination, and decided to produce trichlorosilane (TCS) in a fluidized bed reactor from metallurgical silicon, hydrogen and silicon tetrachloride (STC) [1]. This fluidized bed reactor works at higher temperatures and pressures as compared to the traditional one fed with metallurgical silicon and HCl, and has a great cost reduction potential mainly because it avoids the need of conversion of the STC produced as a by-product in the CVD reactor. Nevertheless, the plant will also include a fixed bed reactor for Si hydroclorination to consume the hydrogen chloride of the CVD reactor effluent and to give flexibility to the installation. Hydrogen purification devices are used in order to close-loop recycle high quality hydrogen to the process.

The fluid dynamic conditions required to deposit polysilicon in the CVD reactor have also been modeled, analyzing the dependence of the growth rate, deposition efficiency, and power loss on some relevant variables such as the gas velocity, the mixture of gas composition the rod surface temperature, etc. [2]. This modeling has been combined with an analysis of the radiative energy loss for several reactor configurations, aiming at diminishing it [3].

Laboratory prototypes have been constructed to gain knowledge on the process, in particular a fixed bed reactor for the synthesis of chlorosilanes, and a one seed-rod polysilicon reactor to validate the information obtained through the aforementioned model (Figure 2).

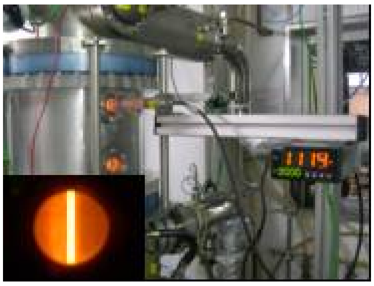

Figure 2: The single-rod CVD reactor in operation, with a closer view of the heated rod.

3.2 Status of the project

The conceptual design and detailed design of the polysilicon pilot plant have been developed. P&ID, material balances and equipment specifications have been established for the different areas of the plant. Purchases of the different pieces of equipment are now taking place, and their installation is currently being developed.

A Cz grower is already installed and operative, producing 8' ingots, and the solar cell processing line of the Instituto de Energía Solar is being moved to the new site.

The whole installation is planned to be ready by mid of 2011, as can be seen in Figure 3.

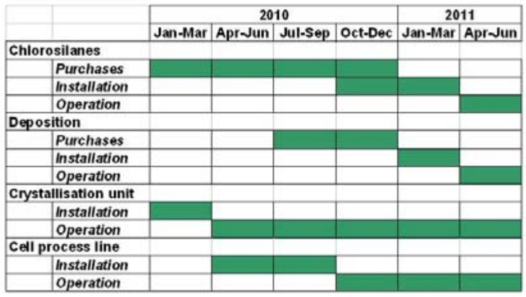

Figure 3: Time schedule for the operation of the CENTESIL plant.

4 COST OF AN INDUSTRIAL PLANT

The experience already gained in designing the pilot plant has allowed us to make a first estimate of the cost breakdown for an industrial plant of around 3000 t/a. For instance, with the technology we can recommend today we think an investment of 81 €/kg is required, of which almost two thirds correspond to the deposition area (see Figure 4).

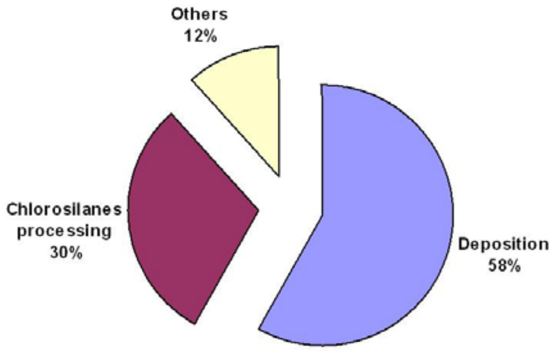

Figure 4: Investment breakdown estimated for a 3000 t/a polysilicon plant.

The operational cost for such an industrial plant can be around 26 €/kg, distributed as shown in Figure 5, with an electricity price of 8 c€/kWh and 10 years for equipment depreciation.

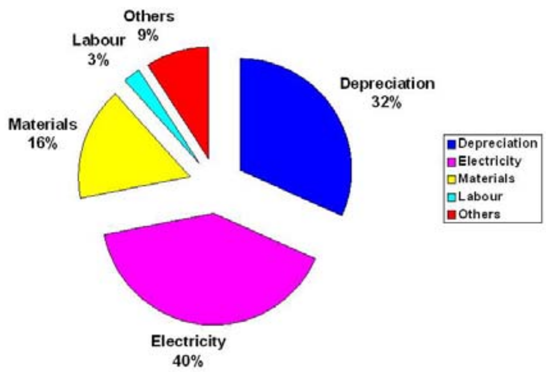

Figure 5: Breakdown of operational costs for a 3000 t/a polysilicon plant, with an electricity price of 8 c€/kWh and 10 years for equipment depreciation.

On the other hand, we believe that the polysilicon cost can be significantly decreased while keeping a quality that would permit manufacturing high efficiency cells. CENTESIL will provide a platform to propose and test innovations and new ideas to achieve this goal.

5 CONCLUSIONS

CENTESIL is an initiative to build an R&D pilot plant for polysilicon purification adapted to photovoltaic applications. It has started with a classical modernised technology, but in the future, and as far as improvements are invented, modifications will be incorporated to this process.

At this moment CENTESIL already has a technology to recommend to potential customers. It knows its approximate cost and where further R&D might reduce it substantially.

To our knowledge, this is the only research centre worldwide developing polysilicon at the pilot plant scale that is not linked to a polysilicon manufacturer. CENTESIL is to become a commercial technology provider of polysilicon technology.

6 ACKNOWLEDGEMENTS

The Spanish Ministerio de Ciencia e Innovación and the Fondo Europeo de Desarrollo Regional are greatly acknowledged for their support through projects PSE-120000-2007-3 and PEN-120000-2009-35.

7 REFERENCES

[1] L. Méndez, PhD. Thesis, Universidad Complutense de Madrid, Madrid, 2009.
[2] G. del Coso, C. del Cañizo, A. Luque, J. Electrochem. Soc. 155(6) (2008) 489.
[3] G. del Coso, C. del Cañizo, A. Luque, *Disclosing the polysilicon decomposition process*, this conference.